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This analysis of establishment-level call center survey data from 14 countries in 2003–2006 explores relationships among technology, selection, and training for both newly hired and more experienced workers. The findings suggest, consistent with the more generic literature, that information and communication technology (ICT) increased training investments. However, the effects on both training and informal learning in the first year differed by technology type. Workflow automation technologies had particularly strong influence on training demands for newly hired agents in call centers. In contrast, interaction automation technologies (such as interactive voice response and speech recognition) and enhanced interaction technologies (such as media blending, electronic customer relationship management, and web-enablement) only led to more ongoing training, and interaction automation technologies had a negative relationship with informal learning in the first year. The findings also suggest that call centers with high levels of ICT recruited a work force with higher returns to training.

Research has shown that the use of information and communication technologies (ICT) has led to an increase in the demand for skill (for example, Autor, Katz, and Krueger 1998), because jobs entailing expert thinking and complex communication are increasing in number while routine manual and cognitive jobs are declining (Levy and Murnane 2004). Companies can deal with the increased demand for skill related to technology by hiring selectively as well as by investing in training. The use of these strategies has been confirmed in several empirical studies in the United States (Bartel and Sicherman 1998; Brynjolfsson and Hitt 1998; Bresnahan, Brynjolfsson, and Hitt 2002), Canada (Baldwin, Gray, and Johnson 1995; Baldwin and Peters 2001) and Europe (Hempell 2003; Giuri, Torrisi, and Zinovyeva 2006).

In this paper, we examine the relationship between ICT and the two skill acquisition strategies (training and selective hiring) in call centers. Our focus on one narrowly defined industry sector enables us to investigate this relationship in more detail than previous

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literature, which was often based either on aggregated data or on cross-industry studies that forced analysts to examine general and broadly defined measures of ICT. Moreover, call centers make more intensive use of ICT than do firms in most other industry sectors. However, there are important differences between call centers in terms of the technologies used and the skills demanded (Deery and Kinnie 2004), which is why we distinguish three specific types of call center technologies: (1) interaction automation technologies, which foster the automation of customer interactions, such as interactive voice response and speech recognition systems, (2) workflow automation technologies, which automate and standardize the internal organization of work, and (3) enhanced interaction technologies, which include media blending, electronic customer relationship management systems, and web-enablement. As far as we know, there are no empirical studies investigating the relationship between ICT and training participation in call centers. Most of the literature on technology in these establishments is related to its potential to control and monitor the "core workers" (Osterman 2000), that is, call center agents (Fernie and Metcalf 1998; Taylor and Bain 1999; Holman, Chissick, and Totterdell 2002; Callaghan and Thompson 2002).[1] Other strands of literature on ICT are more normative, as they describe how specific technologies should be implemented (Gherardi 1999; Cena and Torre 2006).

To provide a comprehensive picture of skill development in call centers, our workplace-level analysis will test for whether the three above-named technologies are related to formal initial and ongoing training, as well as to informal learning[2] of agents. Newly hired agents usually are extensively trained before they actually start working, because call center work is quite specific in its nature and hardly any vocational training exists in formal education (see Sieben and de Grip 2004). Next to initial training programs for newly hired agents, centers also invest in ongoing training for their more experienced agents, for example to inform them about new products or product updates, or to improve their sales techniques. Finally, as in most other industry sectors, informal or on-the-job learning is very important in these establishments. Most newly hired agents are involved in a period of mentoring, during which more experienced workers or supervisors sit next to them and listen in on their calls in order to give feedback and help with customer interactions.

In addition, we pay attention to call centers' selective hiring strategies, because the demand for skill can also be met by hiring employees who are better qualified and more motivated. Centers with higher training demands due to the use of ICT will therefore probably have stricter selection and recruitment practices, as they would like to select applicants with the highest returns to training—that is, highly trainable employees who are committed to stay with the firm.

New Technology and the Demand for Skill

In the literature on the impact of ICT on the demand for skill, two different views have emerged. On the one hand, some argue that ICT is a substitute for workers who perform simple or well-defined tasks (Cooley 1986; Shaiken 1985). Others state that ICT complements work processes that involve more difficult tasks such as problem solving and complex communication activities (Kern and Schumann 1984). In either case, these strands of research claim that ICT increases the demand for skill. Several studies have found that, in general, technology increases the complexity of jobs (Autor, Levy, and

[1]The relationship between the use of the potential in ICT for monitoring and control and the demand for skill is an interesting one, as the consequences of more extensive use of ICT might differ depending on managerial practices. Hunter and Lafkas (2003) reported a study in which the combination of extensive routine automation and low involvement work practices led to lower educational requirements and more initial training. We tried to test for the presence of the same relationship in our models, but found that terms interacting ICT with employee involvement practices had no statistically significant effects on training.

[2]Information on informal training is limited to the first year, in which call center agents receive most informal training.

Murnane 2003; Doms, Dunn, and Troske 1997; Athey and Stern 2002; Spitz-Oener 2006) and the skill level of workers (Keefe 1991; Groot and de Grip 1991). As Levy and Murnane (2004:30) stated, "Computers excel at the rapid application of rules" and fast processing of calculations. This means that computers can substitute for a human agent if customers' requests are simple, such as "I want to buy two black chairs, product number 01234. They should be delivered at ..." or "Please tell me the monthly pay rate for a mortgage of..." But in cases where perceptual problems, contextual knowledge, or feelings are involved, or where numerous exceptions apply, the substitution of a human agent by a machine is complicated or impossible. Computers are limited in their capacity to understand meaning, and therefore human interactions with a computer only work within a limited framework of rule-based selections (Suchman 1999). Hence, in a computer-based dialogue, customers are allowed only a limited number of response categories. In cases where the computer cannot substitute for humans, it can often complement human action by providing a complex set of data that may be handled by the call center agent. In sum, computers may be used to automate away simple, repetitive, rule-based tasks or calculations. However, a range of activities from non-routine, manual tasks to expert knowledge have to be left to humans (Goos and Manning 2007).

Building on the seminal work of Braverman (1974), another strand of research that focuses on technological change in general argues that new technologies can also "downgrade" the skill content of jobs (Spenner 1985; Wood 1987; Goos and Manning 2007). This is particularly relevant when technologies are used to standardize and simplify work tasks in a Taylorist fashion. Moreover, managers may use technologies to increase control and decrease workers' autonomy (Noble 1984). Thus, whether ICT affects the demand for skill positively or negatively is an empirical question that has to be answered with regard to specific types of technologies and tasks. In general, we could say that interaction automation technologies are similar to what Hunter and Lafkas (2003) call ICT for routine automation (working as a substitute), whereas enhanced interaction technologies mainly comprise ICT that automates the support of non-routine processes (working as a complement). Workflow automation can be seen as a technology that lies somewhere in-between.

Interaction Automation Technologies

In one important category are call center technologies that foster the *automation of the customer interaction* or parts of this interaction. Relatively simple inquiries can be completed without contact with a human agent (account information, reporting of data, information on opening hours); reception and switchboard services can be automated with computer-based redirection of calls. Interaction automation can be realized through the implementation of Voice Response Units (VRU), Interactive Voice Response (IVR) systems, and speech recognition systems. VRU is a system for conveying recorded messages. It is used to greet the customer and to provide basic information about, for example, queue time, opening hours, or alternative ways to contact the company. It thereby frees the call center agent from repetitive tasks. IVR makes it possible for customers to interact with the information system via touch-tone telephone keys. They may choose from a menu, or provide a customer or account number. In addition, IVR may work as an interface to banking systems. Speech technology is an alternative or supplement to touch-tone systems that enables a dialogue between the customer and the computer based on synthetic speech messages and speech recognition.

The use of these interaction automation technologies can affect the skill requirements of jobs and, in turn, training, through different scenarios. Automation increases the demand for skill and training by working as a substitute for simple, repetitive tasks, leaving the more complex tasks for employees to carry out (Hunter and Lafkas 2003; Richardson and Gillespie 2003). IVR systems may also be used to separate incoming calls by level of complexity and assign different workers to jobs with different skill requirements, thereby creating more fragmented

or narrow jobs. Call centers that segment customers by their value added, for example, may use interaction automation technologies for segmentation, such that workers serving the mass market handle simpler requests and those serving business clients handle more complex ones (Batt 2000; Batt, Hunter, and Wilk 2003). This implies an internal variation in skill demands that would lower the demand for skill for one group of workers and increase it for another one. Given these different scenarios, it is not easy to theoretically predict the overall relationship between customer automation technologies and training, which consequently becomes an empirical question. We therefore formulate two competing hypotheses:

Hypothesis 1a: Interaction automation technologies are positively related to the amount of initial training, informal learning in the first year, and ongoing training.

Hypothesis 1b: Interaction automation technologies are negatively related to the amount of initial training, informal learning in the first year, and ongoing training.

Workflow Automation Technologies

Like interaction automation technologies, *workflow automation technologies* are used to automate and standardize work processes. However, these technologies focus on the internal organization of work. Workflow management systems can be used to automate the distribution of calls and the flow of tasks, enable skill-based routing, and facilitate resource planning and staffing. Based on call or IVR information, these systems can determine whether a call should be treated as a premium customer call or not, and at which location and by which team the call should be handled. This means that task allocation is not left to workers' or teams' discretion, but is decided by the system itself, based on built-in rules. Workflow automation technologies can also be used to integrate the processing of tasks with other parts of the organization such as billing, sales, or distribution. Organizations in which workers mainly perform simple tasks will benefit less from workflow automation. Therefore, it is likely that these technologies are implemented in organizations that deal with complex tasks.

Regarding the relationship with skills and training, one scenario is that call centers use skill-based routing to link specific customer groups or types of inquiries to specific employee groups, thereby creating more fragmented or narrow jobs (Batt, Hunter, and Wilk 2003). However, another scenario that is backed up by our case-study research[3] is that workflow automation increases these establishments' overall ability to handle complex tasks that involve several agents with specialized skills or interactions with back-office functions. In that case, it can be expected that the use of workflow automation technologies will raise jobs' skill and training requirements. Furthermore, agents have to be trained to interact with workflow management systems.

Hypothesis 2: Workflow automation technologies are positively related to the amount of initial training, informal learning in the first year, and ongoing training.

Enhanced Interaction Technologies

Enhanced interaction technologies include media blending, electronic customer relationship management (E-CRM) systems, and web-enablement. "Media blending" allows call center agents to use a mixture of media to interact with customers—including integrated use of e-mailing, faxing, telephoning, electronic chatting, and video conferencing. A quite sophisticated example we found in our case studies was a financial center where customers and agents could arrange web-cam conferences in which documents and spreadsheets were shared. We expect these technologies to be positively related to the demand for skill, as they require agents to master several types of technical systems and communication skills, such as writing skills and social interaction skills. Media blending not only provides additional options for customers, but also can be used by

[3]In all countries, several case studies of in-house and subcontracting call centers in different industries were conducted, which included extensive interviews with general managers, HR managers, IT specialists, supervisors, and agents.

agents or management as an option for job enrichment. The variety of work tasks can be increased by switching between different activities. In addition, E-CRM systems are important for call centers that have repeated interactions with the same customers, as agents can retrieve and store information about each interaction with the customer in these systems. Thus, customer interactions can be personalized even when the customer interacts with different agents. By making the customer's complete history available, these systems spare agents from having to ask trivial questions that have already been explained to other agents. The complexity of E-CRM systems often requires multi-tasking skills: agents often have to talk to the customer and at the same time search for and assess records of prior customer contacts, fill in new customer data, and log information. Furthermore, E-CRM systems make it possible for the call center to handle more complex tasks. Finally, web-enablement is a technology that enables employees to use intranet and Internet sources, such as knowledge databases, joint browsing, and electronic chatting. This increases both the variety and the complexity of customer interactions.

To summarize, enhanced interaction technologies can be seen as complementing work processes that involve more difficult tasks (Hunter and Lafkas 2003). These technologies will therefore increase the demand for skill in call centers, which is expected to affect training.

Hypothesis 3: Enhanced interaction technologies are positively related to the amount of initial training, informal learning in the first year, and ongoing training.

Selective Hiring Strategies

When call centers that use more advanced ICT have higher skill demands, it can be expected that they will be more selective when hiring new workers, because those organizations that have to train their agents face a large risk of losing these training investments when agents leave the firm. The notoriously high turnover rates in this sector underscore the relevance of selective hiring. Therefore, call centers with heavy training demands are likely to select employees who fit the organization best, as these employees will stay longer in the firm. Selective hiring strategies usually focus on workers' competencies as well as behaviors and attitudes (Becker and Huselid 1999). In particular, systematic selection tests, such as psychometric tests and aptitude tests, may help centers to hire agents who have the best match with the firm and the contents of their job (Terpstra and Rozell 1993). Moreover, centers that have to invest in the training of their agents will select the better-qualified employees from the existing labor pool available, because the trainability of these employees is usually higher (Thurow 1975).

Hypothesis 4: Selective hiring is positively related to the amount of initial training, informal learning in the first year, and ongoing training.

Data, Measures, and Descriptive Statistics

To test the above hypotheses, we employ data from the Global Call Center Project. More information on the survey and the measurement of specific variables is given in the introduction to this special issue (Batt, Holman, and Holtgrewe 2009). We use the information available for Austria, Brazil, Canada, Denmark, France, Germany, Ireland, Israel, Korea, Poland, Spain, Sweden, United Kingdom, and the United States. For three countries (South Africa, India, and the Netherlands), the information on key variables like call center training or technologies was insufficient for our analyses.

Measures and Descriptive Statistics

Our dependent variables all are single-item measures of training in call centers. Initial training is the number of initial training days that agents receive in their first year of appointment, including orientation and induction training. Table 1 shows that agents, on average, received 22 days of initial training. This initial training period is longer than that for clerical workers in general, with whom call center workers are frequently compared (Belt, Richardson, and Webster 2002).

Informal learning, which employees acquire by watching other workers, taking

Table 1. Means, Standard Deviations, and Correlations between Variables.

		Mean	*S.D.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
1	Initial Training	22.01	19.37	–																	
2	Ongoing Training	9.83	10.63	.35	–																
3	Informal Learning	17.47	16.83	.42	.16	–															
4	Interaction Automation Technologies	.34	–	.11	.11	.03	–														
5	Enhanced Interaction Technologies	.24	–	.04	.17	–.01	.18	–													
6	Workflow Automation Technologies	.36	–	.11	.16	.04	.20	.31	–												
7	Selective Hiring	57.55	30.09	.19	.11	.13	.04	.12	.19	–											
8	Size of Call Center	191.03	669.46	.14	.20	.07	.32	.25	.24	.14	–										
9	Age of Call Center	10.77	9.91	.02	–.05	.11	.07	.01	–.06	–.04	.02	–									
10	Part of Larger Organization	.81	–	.17	.07	.09	.09	–.01	.06	.05	.09	–.03	–								
11	In-House Call Center	.68	–	.18	–.02	.18	.04	–.08	–.05	.03	–.16	.14	.32	–							
12	Largest Volume of Calls Inbound	.80	–	.29	.06	.23	.16	.00	.07	.06	.02	.05	.23	.33	–						
13	Sector: Financial Services	.22	–	.14	.01	.10	.10	–.04	.10	.05	.08	–.07	.08	.10	.06	–					
14	Sector: Telecommunication	.30	–	–.02	.06	–.03	.07	.12	.03	–.04	.08	.06	.01	.00	.04	–.34	–				
15	Sector: Other	.48	–	–.10	–.06	–.05	–.14	–.08	–.11	.00	–.13	.01	–.07	–.08	–.08	–.51	–.63	–			
16	Customer Segment: Large Business	.19	–	–.04	–.03	–.03	–.07	.09	–.01	–.01	–.03	.03	–.08	–.14	–.17	–.07	.03	.03	–		
17	Education: School ≤ Age 15/16	.29	–	–.07	.03	–.03	.01	.05	.07	–.02	.09	.02	–.03	–.08	–.02	–.06	.05	.00	.01	–	
18	Education: School > Age 16, ≤ Age 18	.49	–	–.01	–.02	–.01	.03	–.09	–.04	–.04	.00	–.05	.00	–.03	.03	–.02	–.02	.03	–.07	–.63	–
19	Education: University Degree or Equiv.	.22	–	.09	.00	.05	.06	–.04	–.03	.07	–.10	.04	.04	.12	–.01	.09	–.04	–.04	.07	–.34	–.52

Correlations larger than .04 are significant at p = .05 or below.

instructions, receiving supervision provided by supervisors or co-workers (Barron, Black, and Loewenstein 1989), or simply doing their work ("learning by doing"; Arrow 1962), is not so easy to measure in surveys (Bishop 1997; Veum 1995). The learning process depends on coincidental work situations, and there is no well-defined curriculum, which is why most studies use tenure as a proxy for informal learning (for example, Groot and Maassen van den Brink 2000). We employ another proxy, which focuses on informal learning in the first year: the number of weeks it takes full-time agents to become fully competent in their job. Our case studies suggest that new agents who were not proficient in their job received informal feedback, coaching, and supervision until they reached an adequate level of performance in their job. On average, call center agents needed 18 weeks to become fully competent in their job.

Finally, ongoing training is the number of formal training days (including on-line, vendor, classroom, or other formal training) for experienced agents in the year of the survey. Annual ongoing training was considerably less extensive than initial training: on average, experienced call center agents received about 10 days of training per year. In general, centers that provided more initial training for their agents also provided more informal learning in the first year and more ongoing training. The correlation between initial training and informal learning is positive and statistically significant ($r = .415$); the same holds for the correlation between initial training and ongoing training ($r = .353$). The correlation between informal learning and ongoing training is also positive and statistically significant, but much lower ($r = .157$) than the correlation between initial training and informal learning. Differences between countries in the amount of training for newly hired and more experienced workers point in this direction as well. For example, considerable training was received by agents in Brazil, both new employees (26 days) and more experienced workers (18 days). Call centers in Israel, on the other hand, provided less initial (18 days) and ongoing (5 days) formal training, as well as less informal learning (7 weeks).

Interaction automation technologies are measured by averaging two dichotomous items: regular use of VRU or IVR, and regular use of speech recognition.[4] About one-third of the call centers used interaction automation technologies, mainly through VRU or IVR. These technologies were used extensively in Poland (48%) and the United States (40%), but scarcely at all in Germany and Austria (8%). Speech recognition[5] was not very widespread; about 10% of the establishments in our sample used this technology. There is a national component to these automation systems, as speech recognition support is not equally well developed in all languages. In addition, customers' acceptance of automated interactions differs between countries, as is the case for new technologies in general (Porter 1990). Spain had the largest percentage of centers using speech recognition—38%.

Workflow automation technologies are measured by the regular use of workflow management. On average, 36% of call centers used workflow management tools.[6] This percentage was very high in South Korea (88%) and very low in Sweden (4%).

Enhanced interaction technologies are measured by averaging three dichotomous items: regular use of media blending, regular use of E-CRM systems, and regular use of web-enablement.[7] These technologies were more common than the interaction automation

[4]Both items correlate modestly but significantly ($r = .256$). Additional analyses show that our training results for interaction automation technologies are not driven by any of the components of this scale.

[5]It should be noted that the question about speech recognition in the survey may be a bit misleading, as call center agents normally do not use speech recognition in their interactions with customers. Speech recognition systems are used on the call center level in line with or integrated into VRU/IVR systems (Anton 2000).

[6]For U.S. call centers, we do not have information on workflow automation technologies.

[7]Correlations between the three items are $r = .184$ (between electronic CRM and media blending), $r = .247$ (between media blending and web-enablement), and $r = .313$ (between electronic CRM and web-enablement). Additional analyses show that the results for initial training and for informal learning in the first year are not driven by any of the components of the scale. For ongoing training, it is mainly electronic customer relationship management systems and web-enablement

technologies: 57% of all call centers in our sample used media blending, E-CRM, or web-enablement. Sweden is an exception here: in this country, less than 20% of the centers had implemented one of these technologies.

Selective hiring is defined by averaging two measures: the use of systematic selection tests, such as psychometric tests or aptitude tests, and the percentage of applicants actually hired. On average, these tests were used in selecting 46% of agents. In Israel and Brazil, these tests were especially popular, being used to help select, respectively, 77% and 73% of agents. The percentage of applicants actually hired is reverse-coded, as organizations that were more selective had lower percentages of applicants hired. The average call center turns out to have been highly selective: only 28% of all applicants were hired. Most selective were Swedish centers, which employed only one new agent for every six applicants; least selective, South Korean and Brazilian centers, where the ratio was one agent hired for every three applicants.

Of course, training and selective hiring are not influenced by ICT only, but also by many other job, firm, and worker characteristics (Bishop 1997). We therefore control for a number of characteristics that prior research has shown to be relevant for explaining training: firm size, age of the establishment, being part of a larger organization, in-house call center or subcontractor, dealing with inbound calls or outbound calls, sector of industry, and primary customer segment.[8] Table 1 shows that the average establishment in our sample employed about 190 workers and had been in business for 11 years. 81% of the centers were part of a larger organization; 68% were in-house centers that provided services to their company's own customers. Four out of five call centers mainly dealt with inbound calls (calls from customers to the call center). 30% of the establishments in our sample worked in telecommunications, 22% handled financial services, and the rest operated in another industry sector. 19% of the centers served large business or institutions. We also control for agents' educational level, which is measured by using country-specific education levels. In order to have a comparable cross-national measure of education, three education levels were classified: (1) no qualification, or school up to age 15 or 16, (2) school up to age 18 (such as high school equivalent), and (3) university degree or equivalent. 49% of the centers reported that the typical agent had received schooling up to the age of 18. In addition, 22% of the call centers employed agents who typically had a university degree or equivalent. This means that the call center work force in our sample had more education than is commonly ascribed to these workers.

Results

In order to see how different types of ICT were related to training in call centers, we performed negative binomial regression analyses, which take account of the fact that our dependent training variables are left-censored count data (Gardner, Mulvey, and Shaw 1995). First, we discuss the estimation results for initial training, followed by the results for informal learning in the first year and for ongoing training, respectively. Tables 2, 3, and 4, in which we present the estimation results of these analyses, have the same structure. The first column shows the estimation results for the relationship between technologies used and training (Model A). In the next column we include selective hiring in the analyses (Model B). Moreover, as we do not have data on workflow automation technologies used by U.S. call centers, we first show these estimation results for all countries we have in our dataset without the workflow automation variable. Then, we present the estimation results of analyses without the United States, in which we included the workflow automation technologies. Again, we first show the results for the relation-

that show positive effects. Media blending seems to be unimportant when it comes to predicting the amount of ongoing training. Information from our case studies reveals that only very few call centers used media blending in an enhanced way that would demand substantial ongoing training. Most media blending was done by using phone-fax-email contacts.

[8]We exclude union coverage as a control. Sensitivity analyses confirm that models including this variable give the same qualitative results as the models shown here.

ships between ICT and training (Model C), followed by the results of analyses in which we include selective hiring (Model D). In all models, we include the control variables discussed in the previous section. In addition, we control for country-specific effects by including country dummies.[9]

Initial Training

The results of the negative binomial regression analyses for initial training are presented in Table 2. We see in Model A that neither interaction automation technologies nor enhanced interaction technologies were significantly related to initial training at the call center level. This contradicts hypotheses 1a, 1b, and 3. However, the rejection of hypotheses 1a and 1b might be due to countervailing effects (the positive effect expected in 1a might be outbalanced by the negative effect expected in 1b, resulting in no effect at all), whereas the rejection of hypothesis 3 might be explained by observations from our case studies that new agents were assigned to relatively simple tasks and that the full complexity of call center systems was mainly affecting experienced agents. Model B shows that, consistent with hypothesis 4, selective hiring had a highly statistically significant positive relationship with the initial training provided to call center agents. When we exclude the United States and introduce workflow automation technology in Model C, we see that workflow automation was positively associated with initial training (hypothesis 2). Call centers that employed workflow automation technologies on average provided 1.1 days of extra initial training. To make sure that U.S.-specific effects do not blur these relationships, we also ran a regression without workflow automation technologies excluding the United States. The effects were stable. Finally, Model D shows that selective hiring remains statistically significant and slightly reduces the relationships between call center technologies and agents' participation in initial training. The effect of workflow automation diminishes by about 10% after we include selective hiring in the analyses. This means that these establishments, through selective hiring, were able to save on the period of initial training that was needed when workflow automation technologies were used.

The estimation results in Table 2 further show that the number of training days in the first year depended on the size of the call center: larger organizations provided more training (see, for example, Bishop 1997). In addition, older centers provided more initial training. Both effects lose their statistical significance once we exclude the United States and introduce workflow automation technologies in our analyses. In-house centers provided more initial training to their agents than did subcontractors (de Grip, Sieben, and van Jaarsveld 2006). More initial training was also provided in call centers that mainly dealt with inbound calls, and in those that served banking (financial services) or telecommunications. Moreover, centers that employed agents with university degrees offered more initial training than those with less qualified agents. This shows that initial training was not a substitute for initial education; on the contrary, training was a complement to education (Thurow 1975; Heckman 2000). The effect of education disappears, however, when we exclude the United States from our analyses, showing that the complementarity between training and initial education occurred mainly in the United States. Looking at the country dummies, we find that some countries differ significantly from the reference countries, the United States and the United Kingdom. In particular, call centers in Brazil, Canada, Sweden, and the United Kingdom provided substantially more initial training to their

[9]Another way to control for this country specificity would be to use hierarchical models in which call centers are nested within countries. In additional (OLS regression) analyses, we allowed intra-group (country) correlation for standard errors, thereby relaxing the assumption that observations should be independent. This did not change our results at all, with one exception: the effect of interaction automation technologies on initial training became positive and statistically significant when we controlled for selective hiring (Model B in Table 2). As this result only came up in one out of twelve models estimated, we did not report the findings from these supplemental analyses in our tables. Moreover, our theoretical model includes no predictions on specific country-level effects.

Table 2. Number of Initial Training Days in First Year.
(results of negative binomial regression analyses)

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Technologies				
Interaction Automation Technologies[a]	.052	.027	.004	−.020
	(.054)	(.054)	(.071)	(.072)
Workflow Automation Technologies	–	–	.124***	.112**
			(.047)	(.047)
Enhanced Interaction Technologies	.071	.065	.064	.041
	(.057)	(.057)	(.070)	(.071)
Selective Hiring				
Selective Hiring	–	.003***	–	.003***
		(.001)		(.001)
Controls				
Size (log of number of agents)	.039***	.032**	.030*	.024
	(.014)	(.015)	(.016)	(.016)
Age of Call Center (in years)	.064**	.072**	.040	.045
	(.028)	(.028)	(.031)	(.032)
Part of Larger Organization	.067	.071	.037	.045
	(.050)	(.049)	(.057)	(.057)
In-House Call Center	.205***	.194***	.188***	.177***
	(.045)	(.045)	(.050)	(.050)
Largest Volume of Calls Inbound	.453***	.447***	.475***	.460***
	(.048)	(.048)	(.054)	(.053)
Sector				
Financial Services	.222***	.231***	.165***	.167***
	(.046)	(.046)	(.051)	(.051)
Telecommunications	.101**	.111**	.094*	.112**
	(.043)	(.043)	(.051)	(.051)
Other	Ref.	Ref.	Ref.	Ref.
Customer Segment				
Large Business	.062	.061	.018	.010
	(.046)	(.046)	(.053)	(.053)
Other	Ref.	Ref.	Ref.	Ref.
Education of Typical Agent				
School ≤ Age 15/16	Ref.	Ref.	Ref.	Ref.
Schooling > Age 16, ≤ Age 18	.072	.084	−.012	−.014
	(.050)	(.051)	(.063)	(.064)
University Degree or Equivalent	.213***	.192***	.114	.073
	(.059)	(.060)	(.073)	(.075)

Continued

agents than did those in the United States, controlling for other organizational characteristics such as size, age, and sector. Call centers in Israel and South Korea, on the other hand, typically provided less initial training than those in the United Kingdom.[10]

Informal Learning in the First Year

Table 3 shows the results from the negative binomial regression analyses of informal call center learning, one form of learning new

[10]These country differences suggest that some theoretically based segmentation of countries might strengthen our results. However, the differences provide no clear evidence to support the varieties of capitalism model used in other studies in this volume, which is why we did not pursue this any further.

Table 2. Continued.

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Country				
Austria	.232**	.246**	−.157	−.106
	(.101)	(.100)	(.110)	(.110)
Brazil	.545***	.505***	.170	.171*
	(.090)	(.090)	(.103)	(.103)
Canada	.316***	.302***	.031	.065
	(.065)	(.065)	(.083)	(.083)
Denmark	.194**	.158	−.098	−.083
	(.098)	(.100)	(.108)	(.111)
France	.222***	.221***	−.047	.008
	(.074)	(.075)	(.093)	(.094)
Germany	.281***	.271***	−.106	−.079
	(.089)	(.088)	(.100)	(.100)
Ireland	.114	.110	−.198	−.156
	(.133)	(.132)	(.139)	(.138)
Israel	.086	.002	−.269**	−.306***
	(.100)	(.102)	(.112)	(.112)
South-Korea	.060	.022	−.312***	.297***
	(.088)	(.091)	(.110)	(.108)
Poland	.084	.084	−.201	−.147
	(.110)	(.110)	(.126)	(.126)
Spain	.088	.046	−.200	−.191
	(.111)	(.112)	(.122)	(.123)
Sweden	.340***	.359***	.069	.132
	(.085)	(.085)	(.099)	(.100)
United Kingdom	.326***	.283***		
	(.081)	(.081)	Ref.	Ref.
United States	Ref.	Ref.	–	–
Constant	1.787***	1.639***	2.265***	2.098***
	(.121)	(.124)	(.128)	(.133)
Log Likelihood	−8,151.020	−7,975.473	−6,410.099	−6,255.486

Notes: Models A and B: all countries (n = 1,996); Models C and D: all countries without U.S. (n = 1,558). Unstandardized coefficients; standard errors in parentheses. Ref. = reference category.

[a]For U.S., interaction automation technologies only include use of VRU/IVR.

*Statistically significant at the .10 level; **at the .05 level; ***at the .01 level.

agents must acquire to become fully competent in their jobs. The estimation results show that there was a negative relationship between interaction automation technologies and informal learning in the first year: on average, agents working in centers using these interaction automation technologies needed about one week less to become fully competent. This finding leads us to conclude that interaction automation systems were used to separate incoming calls by level of complexity and to assign agents to jobs with different skill requirements, thereby narrowing the job content for the newly hired agent (hypothesis 1b). Contrary to our expectations formulated in hypothesis 3, enhanced interaction technologies did not affect the extent of informal training. When workflow automation technologies are included in Model C, we see that this technology has a statistically significant positive relationship with informal learning in call centers, consistent with hypothesis 2. This resembles our conclusions on the relationship between ICT

Table 3. Informal Learning: Weeks to Become Fully Competent. (results of negative binomial regression analyses)

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Technologies				
Interaction Automation Technologies[a]	−.139**	−.146**	−.189**	−.183**
	(.057)	(.057)	(.076)	(.077)
Workflow Automation Technologies	–	–	.119**	.086*
			(.049)	(.050)
Enhanced Interaction Technologies	.064	.028	.088	.034
	(.060)	(.061)	(.073)	(.074)
Selective Hiring				
Selective Hiring	–	.003***	–	.003***
		(.001)		(.001)
Controls				
Size (log of number of agents)	−.005	−.016	−.007	−.015
	(.015)	(.015)	(.017)	(.017)
Age of Call Center (in years)	.146***	.150***	.129***	.130***
	(.029)	(.029)	(.033)	(.033)
Part of Larger Organization	−.034	−.045	−.027	−.033
	(.053)	(.053)	(.060)	(.060)
In-House Call Center	.267***	.247***	.222***	.198***
	(.050)	(.050)	(.055)	(.055)
Largest Volume of Calls Inbound	.289***	.296***	.357***	.359***
	(.051)	(.051)	(.057)	(.057)
Sector				
Financial Services	.218***	.236***	.192***	.214***
	(.049)	(.049)	(.054)	(.054)
Telecommunications	.061	.068	.026	.036
	(.046)	(.046)	(.053)	(.054)
Other	Ref.	Ref.	Ref.	Ref.
Customer Segment				
Large Business	−.007	−.028	−.046	−.071
	(.049)	(.049)	(.056)	(.056)
Other	Ref.	Ref.	Ref.	Ref.
Education of Typical Agent				
School ≤ Age 15/16	Ref.	Ref.	Ref.	Ref.
Schooling > Age 16, ≤ Age 18	.068	.052	−.061	−.091
	(.053)	(.054)	(.066)	(.067)
University Degree or Equivalent	.109*	.095	−.019	−.042
	(.063)	(.063)	(.076)	(.078)

Continued

and initial training. Models B and D show that selective hiring was positively related to informal learning in the first year. This is in line with our expectations formulated in hypothesis 4. Moreover, selective hiring reduced the effect of workflow automation technologies on informal learning by 28%.

The estimation results for the control variables to a large extent reflect the estimation results from the analysis to identify the determinants of initial training. Call centers that had been in business longer, we find, had higher levels of informal learning in the first year. In addition, newly hired agents employed by in-house centers had longer periods of informal learning than those

Table 3. Continued.

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Country				
Austria	−.223**	−.207*	−.794***	−.727***
	(.108)	(.108)	(.117)	(.117)
Brazil	.395***	.345***	−.162	−.161
	(.098)	(.098)	(.110)	(.110)
Canada	.300***	.293***	−.142*	−.096
	(.070)	(.069)	(.086)	(.086)
Denmark	.049	−.004	−.395***	−.395***
	(.104)	(.106)	(.112)	(.114)
France	−.051	−.113	−.493***	−.498***
	(.078)	(.080)	(.095)	(.096)
Germany	.323***	.264***	−.279***	−.288***
	(.094)	(.094)	(.105)	(.105)
Ireland	.235*	.237*	−.224	−.177
	(.140)	(.139)	(.144)	(.144)
Israel	−.901***	−.977***	−1.376***	−1.392***
	(.109)	(.110)	(.121)	(.121)
South-Korea	−.285***	−.303***	−.807***	−.756***
	(.095)	(.099)	(.111)	(.114)
Poland	−.535***	−.545***	−.938***	−.896***
	(.118)	(.118)	(.134)	(.134)
Spain	.041	.007	−.405***	−.388***
	(.116)	(.117)	(.124)	(.125)
Sweden	−.082	−.113	−.486***	−.475***
	(.091)	(.092)	(.103)	(.105)
United Kingdom	.491***	.443***	Ref.	Ref.
	(.086)	(.086)		
United States	Ref.	Ref.	–	–
Constant	1.948***	1.853***	2.511***	2.392***
	(.125)	(.128)	(.131)	(.136)
Log Likelihood	−7,772.276	−7,583.554	−6,046.328	−5,876.997

Notes: Models A and B: all countries (n = 2,011); Models C and D: all countries without U.S. (n = 1,571). Unstandardized coefficients; standard errors in parentheses. Ref. = reference category.

[a]For U.S., interaction automation technologies only include use of VRU/IVR.

*Statistically significant at the .10 level; **at the .05 level; ***at the .01 level.

working for subcontractors. The same holds for agents recruited by centers that mainly handled inbound calls or provided financial services. However, we do not find an effect of establishment size, nor do we find that call centers that employed better-educated agents were more involved in informal learning in the first year. This latter finding shows that informal learning was neither a complement to nor a substitute for initial education. Finally, we observe several country differences in the amount of informal learning. Agents working in centers in Israel, Poland, and South Korea needed fewer weeks to become fully competent than agents working in centers in our reference countries, the United States and United Kingdom.

Ongoing Training

The results of the analyses investigating the number of formal training days for experienced call center agents are displayed in Table 4. In Model A, we see that enhanced

interaction technologies were positively related to centers providing ongoing training (confirming hypothesis 3), whereas the estimates for interaction automation technologies are not statistically significant (rejecting hypotheses 1a, 1b, and 2). However, a model that excludes the United States from this analysis shows a positive effect of interaction automation technologies on ongoing training as well. This indicates that the use of interaction automation technologies in the United States differed from that in the rest of our sample. First, interaction automation technologies were more widely used in the United States: 41% of American call centers employed these technologies, compared to an average of 7% of centers in the other countries studied here. Second, information from our case studies shows that in the United States, interaction automation technologies were used to create narrower jobs with lower skill requirements in specialized call centers, a pattern that is not apparent in other countries. In any case, centers using interaction automation technologies or enhanced interaction technologies on average provided more than one day of extra ongoing training to their agents annually. Model B indicates that selective hiring had a positive impact on ongoing training. In addition, the effect of enhanced interaction technologies on ongoing training decreases significantly after we include selective hiring in our model. When we include workflow automation, we find that interaction automation technologies are also positively associated with the extent of ongoing training in call centers (see Model C). Our estimation results therefore confirm hypotheses 1a and 3 with respect to positive influences of technologies on ongoing training. When we compare these estimation results with those presented in Table 2, it is interesting to see that ongoing training in call centers was more affected by these technologies than was initial training. Model D shows, again, that selective hiring had a positive effect on ongoing training (hypothesis 4). In addition, the inclusion of selective hiring in the model slightly reduce the observed effects of enhanced interaction technologies.

Furthermore, the estimation results show that the amount of ongoing training was positively related to the size of the establishment. When we exclude the United States and include workflow automation technologies in Models C and D, we find that older call centers provided less ongoing training. This contrasts with the positive relationship we found between the age of a call center and informal learning in the first year. In addition, agents working in centers that served large business customers provided less ongoing training. On the other hand, the number of formal training days for experienced agents was not related to the type of center: in-house centers or centers mainly handling inbound calls did not provide more ongoing training than subcontractors or call centers mainly handling outbound calls. Clearly, all agents employed by a call center needed ongoing training to (for example) keep abreast of product or service updates. However, centers employing agents with schooling up to age 15 or 16 offered less ongoing training than those with better-educated agents. This shows that ongoing training to some extent was a complement to initial education. Finally, looking at the country dummies, we again find statistically significant country differences in the provision of ongoing training. Particularly notable is the greater amount of ongoing training provided to agents by centers in Brazil, South Korea, and Spain than by those in the reference countries, the United States and United Kingdom. Call centers in Israel, France, and Denmark, on the other hand, provided less ongoing training.

Discussion and Conclusions

The main objective of this paper has been to explore the relationships between information and communication technology (ICT), on the one hand, and different kinds of training for both newly hired workers (initial formal training and informal learning in the first year) and more experienced workers (ongoing formal training), on the other. In addition, we have paid attention to call centers' selective hiring processes, as ICT not only might lead to higher training investments, but also might make call centers more selective when hiring new

employees who should be trained more intensively.

In general, ICT could affect call center training in different ways. Technologies may substitute for employees who perform limited and well-defined tasks (Cooley 1986; Shaiken 1985). Moreover, ICT could complement work processes that involve more difficult tasks (Kern and Schumann 1984). In both cases, ICT would be related to an increase in the demand for skill and thus higher training needs. Finally, ICT could downgrade the skill content of jobs when tasks are simplified in a Taylorist fashion. In general, our estimation results show that ICT was associated with higher training participation, although not all types of technologies were associated with more training.

First, interaction automation technologies, such as Voice Response Units (VRU) and Interactive Voice Response (IVR) systems and speech recognition, had a positive relationship with ongoing training (hypothesis 1a). Call centers using these technologies provided their agents with, on average, more than one day of extra ongoing training annually than did other call centers. This suggests that these automation technologies take away the more simple, repetitive tasks, while leaving the complex tasks to be handled by agents (Richardson and Gillespie 2003). However, interaction automation technologies did not affect initial formal training, and had a negative relationship with informal learning in the first year (hypothesis 1b). This suggests that these technologies in some cases are used in segmentation strategies to create narrower jobs for newly hired agents in a Taylorist fashion (Wood 1987).

Workflow automation, which is often used in call centers to automate and standardize work processes, was positively related to the training participation of newly hired agents (hypothesis 2). Call centers employing workflow automation technologies offered significantly more initial training (slightly more than one day) and more informal learning in the first year (about one week extra) to their agents than centers that did not use these technologies. This implies that workflow automation in call centers was used to increase the ability to handle complex tasks that involved several agents and repeated customer interactions and not as a way to create narrower, more standardized jobs.

Enhanced interaction technologies, such as media blending, electronic customer relationship management, and web-enablement, positively influenced the number of formal training days experienced agents received (hypothesis 3). Call centers using these enhanced technologies on average provided their agents with one and a third days of extra ongoing training annually. This pattern probably reflects the need for agents to learn more techniques and skills to master these technologies. It is therefore remarkable that we observed no relationship between the enhanced interaction technologies and initial formal training or informal learning. It may be that call centers offer training commensurate with the demands of these complex technologies only when agents are at a later career stage, with more maturity in their work and a better ability to draw on their earlier experiences. Another explanation could be that system changes related to advanced technologies require substantial skill changes, which increase the need for *ongoing* training. Observations from our case studies support the latter view.

Finally, we argued that call centers with higher demand for skills induced by high levels of technology will have more strict selection and recruitment processes. By selecting high-quality employees, firms recruit a work force that is expected to yield high returns on further training and more commitment to stay with the firm. We found that there indeed was a positive relationship between selective hiring and both initial and ongoing formal training and informal learning in the first year (hypothesis 4). Moreover, the inclusion of selective hiring in the analyses substantially decreases the estimated effects of the use of workflow automation technologies on initial training and informal learning in the first year. In addition, selective hiring decreased the effect of enhanced interaction automation on training for more experienced agents. This suggests that more exacting selection of agents enables call centers to save not only on costs of initial training related

Table 4. Number of Ongoing Training Days after the First Year.
(results of negative binomial regression analyses)

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Technologies				
Interaction Automation Technologies[a]	.051	.036	.202**	.195**
	(.060)	(.061)	(.081)	(.083)
Workflow Automation Technologies	–	–	.072	.048
			(.052)	(.053)
Enhanced Interaction Technologies	.296***	.288***	.218***	.204***
	(.064)	(.065)	(.078)	(.078)
Selective Hiring				
Selective Hiring	–	.003***	–	.003***
		(.001)		(.001)
Controls				
Size (log of number of agents)	.038**	.033**	.038**	.036*
	(.016)	(.016)	(.018)	(.018)
Age of Call Center (in years)	–.010	–.009	–.076**	–.076**
	(.032)	(.032)	(.037)	(.038)
Part of Larger Organization	.037	.039	.035	.045
	(.055)	(.055)	(.063)	(.063)
In-House Call Center	.002	.001	.039	.038
	(.050)	(.050)	(.056)	(.056)
Largest Volume of Calls Inbound	.038	.029	.078	.061
	(.053)	(.053)	(.059)	(.059)
Sector				
Financial Services	–.074	–.064	–.078	–.069
	(.052)	(.052)	(.057)	(.058)
Telecommunications	–.016	–.012	–.062	–.058
	(.048)	(.049)	(.057)	(.058)
Other	Ref.	Ref.	Ref.	Ref.
Customer Segment				
Large Business	–.140***	–.144***	–.164***	–.170***
	(.052)	(.052)	(.060)	(.060)
Other	Ref.	Ref.	Ref.	Ref.
Education of Typical Agent				
School ≤ Age 15/16	Ref.	Ref.	Ref.	Ref.
Schooling > Age 16, ≤ Age 18	.181***	.181***	.211***	.201***
	(.056)	(.057)	(.070)	(.072)
University Degree or Equivalent	.157**	.145**	.211**	.184**
	(.067)	(.068)	(.082)	(.085)

Continued

to ICT but also on costs of investments in ongoing training.

All in all, our three hypotheses predicting a positive relationship between the different types of call center technologies and initial training, informal learning in the first year, and ongoing training are only partly confirmed. We found that whereas workflow automation technologies did generate training demands for newly hired agents in these establishments, interaction automation technologies and enhanced interaction technologies only led to more ongoing training. On the one hand, this corroborates reports

Table 4. Continued.

Variable	*Model A*	*Model B*	*Model C*	*Model D*
Country				
Austria	−.091	−.087	.163	.209
	(.115)	(.114)	(.127)	(.128)
Brazil	.557***	.516***	.799***	.794***
	(.097)	(.098)	(.114)	(.114)
Canada	−.196***	−.204***	.015	.050
	(.072)	(.072)	(.093)	(.094)
Denmark	−.498***	−.510***	−.287**	−.257**
	(.112)	(.115)	(.124)	(.127)
France	−.445***	−.479***	−.215**	−.202*
	(.084)	(.087)	(.105)	(.107)
Germany	.193**	.167*	.463***	.474***
	(.095)	(.096)	(.111)	(.110)
Ireland	−.035	−.051	.152	.176
	(.150)	(.150)	(.158)	(.158)
Israel	−.764***	−.823***	−.543***	−.563***
	(.116)	(.118)	(.130)	(.130)
South-Korea	.382***	.366***	.494***	.534***
	(.099)	(.102)	(.116)	(.119)
Poland	.057	.059	.251*	.297**
	(.126)	(.127)	(.143)	(.143)
Spain	.330***	.341***	.536***	.588***
	(.120)	(.121)	(.134)	(.136)
Sweden	−.192*	−.196**	.030	.064
	(.098)	(.098)	(.114)	(.115)
United Kingdom	−.205**	−.242***	Ref.	Ref.
	(.092)	(.092)		
United States	Ref.	Ref.	–	–
Constant	1.938***	1.832***	1.765***	1.616***
	(.137)	(.140)	(.148)	(.154)
Log Likelihood	−6,479.945	−6,348.177	−5,029.964	−4,912.902

Notes: Models A and B: all countries (n = 1,995); Models C and D: all countries without U.S. (n = 1,562). Unstandardized coefficients; standard errors in parentheses. Ref. = reference category.

[a]For U.S., interaction automation technologies only include use of VRU/IVR.

*Statistically significant at the .10 level; **at the .05 level; ***at the .01 level.

in the more generic literature that ICT leads to higher demand for skill and therefore to more training (Autor, Levy, and Murnane 2003). On the other hand, it shows that specific technologies have different effects on training demands.

Future research. Although our analyses are based on a very extensive dataset that includes 14 countries, we were only able to relate training to call center technologies and selective hiring in a cross-sectional analysis. As a result, we were unable to account for the possibility that firms that provide more training might also be inclined to invest more in ICT. However, although we cannot rule out such reverse causality, we think it is not likely in the context of the call center sector. Call centers, which represent a relatively new organizational type that critically depends on the implementation of state-of-the-art technologies, generally use the most advanced and reliable ICT from the first day of operations.

In a similar way, our cross-sectional data

do not allow us to determine the causal relation between selective hiring and training. Moreover, in a cross-sectional design, it is not possible to analyze any changes associated with the introduction of new technologies in call centers. As Hunter and Lafkas (2003) indicated, management style in terms of control versus involvement of workers might be important in this respect. Future research should therefore focus on developing longitudinal data from multiple sources (call center managers, supervisors, and agents). This would also facilitate research to test claims that the introduction of the ICT-based call center production model has initiated a new division of labor, one that, over time, has led to a decrease in the skills required of specific occupational groups due to the fact that particular tasks have moved from traditionally organized service jobs to call center jobs (Batt, Hunter, and Wilk 2003). Such an analysis would require a longitudinal study as well as a study of specific occupations across sectors.

In addition, future research might include examination of the implications of "domain-specific" technologies, that is, the technologies intrinsic to the products for which a call center provides services. The complexity of these technologies, which is a function of inherent characteristics of the associated products (product scope) and also the number and variety of products supported (product scale), may be an important factor. It seems reasonable to speculate that more complex products and related ICT systems might raise the skill levels required of call center agents and thus increase training needs. We therefore suggest developing data on the frequency of product updates, the extensiveness of agents' product portfolio, and the quantity of product documentation.

Furthermore, future research should focus on the relationships among ICT, the demand for skill, and the off-shoring of call center services. Our discussion of the results from our analyses of the impact of call center technologies on training may leave the impression that computers take over simple work tasks, thereby eliminating tedious, repetitive work for agents. However, as previously remarked, the fact that computers can perform rule-based calculations does not mean that they can handle all simple human tasks in call centers. Computers cannot understand the meaning of even simple dialogues, which are not tightly scripted. Therefore, relatively simple, monotonous tasks still have to be performed by agents. To handle this problem, call center managers may choose the strategy of off-shoring services to low-wage countries, which raises the relative demand for skilled workers in the industrialized countries (Levy and Murnane 2004), although it should be noted that in many mostly non-English-speaking countries, the potential for off-shoring call center services is limited by the distribution of language competencies.

Finally, our results address some more general issues for further research on skill-biased technological change and lifelong learning. First, our finding that not all information and communication technologies were associated with increasing training demands is highly relevant for further research on skill-biased technological change and its impact on earnings equality. It might be interesting to distinguish between different kinds of ICT in these analyses. Moreover, our analysis addresses the possibility that the diffusion of ICT has different effects on the demand for initial training, ongoing training, and informal learning in various sectors of industry. Further research in this area could yield deeper insights into the nature of lifelong learning requirements specific to the transition from school to work as well as to ongoing training.

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